AME 521 Engineering Vibrations II

Fall 2024

Department of Mechanical Engineering
University of Southern California

(Created on 2024-0522; Revised on 2024-0717)

Description: 4 units
Multi-degree of freedom systems; continuous systems; gyroscopic systems; modal analysis; beams, rods, strings, shafts; membranes, plates, and cylindrical shells; numerical methods including Rayleigh Ritz method, Galerkin method, assumed-mode method, and finite element methods; application problems.

Prerequisite: AME 420

Instructor	Professor Bingen (Ben) Yang Office: OHE 412F; Phone: (213) 740-7082; Email: bingen@usc.edu
Class Meeting	Monday and Wednesday 6:00-7:50 pm, OHE 100D
Office Hour	Monday and Wednesday 3:30 – 5:00 pm, in office and at Zoom meeting

Course Materials:

Textbook: Bingen Yang, 2025, *Advanced Mechanical Vibration: Modeling, Analysis, and Simulation*, McGraw Hill. (The book is in production now.)

Notes: Class notes and handouts (downloadable from the AME521 website)

References: [1] L. Meirovitch, 2002, *Fundamentals of Vibrations,* McGraw-Hill.

[2] W. J. Bottega, 2014, *Engineering Vibrations*, CRC.

Grading:

Three (3) online midterm exams (110 mins, 23.3% each)	70%
Project	30%
No final exam	
Total	100 %

Homework: 10 sets of non-credit homework problems will be assigned weekly (52 problems for the entire semester). Solutions to the homework will be provided. Timely and independent completion of the homework problems is important to understanding of the course materials, and to good performance in the coursework.

Learning Objectives:

The objectives of this course are:

- To provide students with fundamental theories on linear vibrations for dynamic systems in a variety of engineering applications;
- To train students on how to apply those theories in modeling, analysis, and simulation of vibrating systems; and
- To help students develop skills of handling practical engineering problems.

Topics:

- Review of single-degree-of-freedom systems
- Establishment of equations of motion
    - Newton's laws
    - Lagrange's equations
    - Small oscillation and linearization
- Multi-degree-of-freedom systems
    - Eigenvalue problems and solutions
    - Natural modes of vibration
    - Steady-state response to harmonic excitations
    - Time response via modal analysis
    - Damping in vibrating systems
    - Gyroscopic effects
    - Use of MATLAB in analysis and simulation
- State equations and transfer function formulation
    - State equations and solution via eigenvector expansion and numerical integration
    - Transfer function formulation
    - Distributed transfer function method
- Distributed vibrating systems
    - Calculus of variations
    - Extended Hamilton's principles
    - One-dimensional continua (bars, strings, shafts and beams)
    - Eigenvalue problems
    - Modes of vibration
    - Eigenfunction expansion (modal analysis)
    - Vibration of membranes
    - Vibration of thin plates
- Approximate methods for distributed systems
    - Rayleigh's quotient
    - Assumed modes method
    - Finite element method
- Applications
    - Combined distributed-lumped systems
    - Dynamic vibration absorption
    - Dynamics of structures carrying moving subsystems

AME 521 Website – D2L Brightspace

https://courses.uscden.net.

Contact DEN for any questions on using the website.

Course Schedule

Important Dates			
	2024/09/30	Midterm Exam 1 (110 mins)	Online exam
	2024/10/30	Midterm Exam 2 (110 mins)	Online exam
	2024/12/04	Midterm Exam 3 (110 mins)	Online exam
	2024/12/10	Project report due (Tuesday, by 11:59 pm)	Online submission

Week	Date	Materials Covered/Exams	HW/Project
1	8/26	Review of single-degree-of-freedom systems (AME420 course materials) Textbook: Chapters 1 and 2	
	8/28	Multi-degree-of-freedom (M-DOF) systems: governing equations by Newtonian approach Textbook: Section 3.1	HW 1 - 6 problems: **2.5, 2.14, 2.17, 3.1, 3.5, 3.6**
2	9/2	Labor Day – No class	
	9/4	M-DOF systems: Lagrange Equations Textbook: Section 3.2	
3	9/9	M-DOF systems: linearization, and more examples Textbook: Sections 3.3-3.6	HW 2 – 6 problems: **3.8, 3.12, 3.13, 3.19, 3.22, 4.2**
	9/11	M-DOF systems: eigenvalue problems Textbook: Sections 4.1-4.4	
4	9/16	M-DOF systems: free vibration, modal analysis Textbook: Sections 4.5-4.7	HW3 – 6 problems: **4.3, 4.4, 4.9, 4.13, 4.16, 22**
	9/18	M-DOF systems: modal analysis Textbook: Sections 4.8-4.10	
5	9/23	M-DOF systems: damped systems Textbook: Sections 5.1-5.4	HW4 – 6 problems: **4.23, 4.25, 5.2, 5.5, 5.9, 5.14**
	9/25	M-DOF systems: general mechanical systems, Textbook: Sections 5.5-5.7	Project assignment (due in 76 days)
6	9/30	Midterm Exam 1 – online	
	10/2	Calculus of variations Textbook: Sections 6.1-6.3	
7	10/7	Extended Hamilton's principle, 1-D continua Textbook: Sections 6.4-6.5	HW 5 – 6 problems: **6.2, 6.9, 7.3, 7.4, 7.11, 7.12**

	10/9	1-D distributed systems: governing equations Textbook: Sections 7.1-7.4	
8	10/14	Eigenvalue problems of 1-D continua Textbook: Sections 8.1-8.4	HW 6 – 5 problems: **8.1, 8.5, 8.6, 8.9, 8.13**
	10/16	Orthogonality of eigensolutions, modal analysis Textbook: Sections 8.5-8.6	
9	10/21	Modal analysis of 1-D continua, damped 1-D continua, steady-state response Textbook: Section 8.7-8.10	HW 7 – 5 problems: **8.20, 8.23, 8.25, 8.30, 8.35**
	10/23	Distributed transfer function method (DTFM) Textbook: Section 10.1-10.3	
10	10/28	DTFM: eigensolutions of 1-D continua, stepped systems Textbook: Section 10.4-10.6	HW8 – 4 problems: **10.2, 10.6, 10.7, 10.11**
	10/30	Midterm Exam 2 -- online	
11	11/4	Approximation methods: comparison and admissible functions, Rayleigh Ritz method Textbook: Section 11.1-11.3	HW 9 – 4 problems: **11.1, 11.9, 11.16, 11.21**
	11/6	Approximation: the assumed modes method Textbook: Section 11.4	
12	11/11	Veterans Day – No class	
	11/13	Approximation: the finite element method, application – combined systems Textbook: Sections 11.5 and 12.1	
13	11/18	Application: combined systems Textbook: Section 12.2	HW 10 – 4 problems: **12.2, 12.6, 9.1, 9.4**
	11/20	Application: structures under moving subsystems Textbook: Sections 12.3	
14	11/25	Two-dimensional continua: membranes Textbook: Sections 9.1-9.2	
	11/27	Thanksgiving Break – No class	
15	12/2	Two-dimensional continua: plates Project tips Textbook: Sections 9.3-9.4	HW 10 due
	12/4	Midterm Exam 3 – online	Last class
16	12/10	Project report due on Tuesday by 11:59 PM online submission	